Dynamic Channel Change Proposal For DOCSIS 1.1

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This document represents a submission to DOCSIS and contains

direct quotes from the current DOCSIS specification.

Author's Notes to Reviewers (Rev 0.5, 11/9/99)

The goal of the Dynamic Channel Change command is to allow both the upstream and downstream frequencies to be changed. They are combined into one command so that both may be changed at the same time.

DCC is a direct substitution for UCC. In this proposal, DCC is backwards compatible with the former UCC. If compatibility were not an issue, I would recommend changing the upstream channel ID from a parameter to a TLV in both the DCC-REQ and DCC-GNT. That would allow for either upstream and/or downstream channel IDs to be specified.

After specifying this change, there were a few other "laundry list" items regarding channel changing that needed to be added or clarified.

In general, the main changes I made are:

- Changed UCC to DCC. Added a downstream frequency TLV.
- If the DCC fails, the CM returns to its previous channel instead of re-initializing. This should improve system integrity and trouble-shooting.

The "laundry list" of items I added or changed are:

- Added a registration technique TLV to DCC-REQ. This complements the ranging technique TLV that I had added long ago. Text added to explain both cases.
- Added a success TLV to DCC-RSP. If the change is a failure, then the CM come back to the previous channel and reports a failure. Several failure codes are provided to aid in system integrity.
- Text added to explain how to deal with outstanding bandwidth requests.
- Text added to explain interaction with DCC, UGS services, and QoS reservations.
- CMTS and CM state diagrams updated accordingly.
- Appendix B: The number of UCC-REQ Retries was missing. DCC-REQ Retries added and specified at 3 retries.
- Appendix H.1: Redrew the diagram. Clarified and updated text. Changed MUST to SHOULD on all upstreams being the same frequency. This is to allow for spectrum management techniques.
- Appendix H.2 is completely new and explains the system impacts with DCC.

I have formatted the submission in DOCSIS format. Text marked with a ~~strike-through~~ can be ignored and is to make cross referencing work. Changes that will need to occur elsewhere in the DOCSIS document include:

- Change all "UCC" references to "DCC"
- Change all "Upstream Channel Change" references to "Dynamic Channel Change"

Update on Rev 0.6, 2/14/00

After having the proposal reviewed by the DOCSIS 1.1 committee, I have made the following refinements before submitting this as an ECR:

- **Renumbering:** Section 8 to Section 6. Section 9.3.3 to 9.3.4

- **Unique DCC Command:**
  - DCC will become a separate command from UCC and only apply to DOCSIS 1.1
  - T5 in appendix B lists both commands.
  - Changed UCID from a listed parameter into a TLV parameter for DCC-REQ and DCC-RSP. Renumbered parameters. Added description of registration TLV to DCC-REQ. Updated diagrams.
  - Renamed "Registration TLV" to "Configuration TLV" to better describe its function. I am open to other name possibilities. *(later renamed to Connection TLV 2/17/00)*
- **Maintenance Option:** When the CMTS instructs the CM to use initial or station maintenance, the choice belongs to the CM, not which one comes first. (footnote 6.3.10.1.3)
- **SID/SAID/SFID Substitution on DCC-REQ:** This was the only feature really missing from this proposal. It was part of the original proposal, but I took it out for simplification. I have now put it back in as it gives the CMTS flexibility in how it manages its addressing tables between channels.
- **DCC-RSP**
  - I have defined this as being sent on the old channel only. It is needed there as all CMTS commands are ACKed, and this is how UCC works. On the new channel, the concept is to have UGS operation begin immediately. This means the CM and CMTS cannot afford to wait for a DCC-RSP to propagate to the CMTS before sending data. Without it (current proposal), the CMTS will have to rely on other techniques for detecting the presence of the CM on the new channel. Opinions are welcome on this.
  - Repeating the Upstream Channel ID and the Downstream Frequencies don't seem useful to me. I have left these in here because it was done that way in UCC. I have deleted them.
  - **DCC-Status:** The sole value of this TLV is to support a graceful recovery from sending a CM into never-never land. In theory, this should never happen. In practice, it may, and this option is intended to improve the reliability of connections. The caveat was added that this only applies to channels which did not get re-configured. However, I am concerned that this TLV along with T11 and T12 may create more test cases and corner cases, and might not be worth the complexity. I am open to deleting this.
- **DSx-RSP Confirmation Code:** If CM issues a DSx for more BW, and the CMTS needs to do a DCC to obtain that bandwidth, the CMTS will allow the DSx to be successful and include a return code that the new bandwidth will not be available until a DCC is received. The CMTS will then follow the DSx transaction with a DCC transaction. Comment added to section 9 and section C.4
- **DSx and DCC Glare:** Glare treatment between DSx and DCC. There are two options if the CM issues DSx simultaneous with the CMTS issuing a DCC.
  - (a) CMTS wins. DSx rejected. DCC proceeds. Giving the preference to the CMTS is consistent with the DSx glare scenarios. Or,
  - (b) CM wins. This allows the CMTS to re-evaluate the bandwidth requirements and allows the DCC command to be modified or canceled. This was the recommendation of the DOCSIS 1.1 group so as to avoid altering the DSx state machines (this assumption would be confirmed. Wouldn't the CMTS state machines still be altered?). The potential downside is that a first DSx is given a confirmation code off success-pending-DCC, and the DCC gets delayed by a second

and independent DSx command from the same CM. Another issue is if the second DSx is on a different SID but from the same CM: is this glare? How easy/hard is it for the CMTS to surmise this?

- Although the group had preferred option (b), I have submitted option (a) as I was not comfortable with the potential issues. I am open to discussion on this and am willing to change to (b) if it can be shown to work.
- Also, CMTS should not issue a DSx if a DCC is outstanding, nor should it issue a DCC if a DSx is outstanding.
- Comments added to the end of section 9.

- **Circular References:** If CMTS does a DCC with re-range, the config file could cause the CM to come back to the original channel. This would cause a infinite loop. A note was added that the provisioning system should use either static or dynamic load balancing, not both. There is intentionally no structure which would allow the CMTS to override a config file parameter during registration. Comment added to section 9.
- **Appendix H:**
  - H.1: rewrite of "constraints imposed by this topology" supplied by Victor Hou.
  - MUSTs and SHOULDs in Appendix H set to lower case. Appendix H becomes informative instead of normative.

Update on Rev 0.7, 2/20/00

Grammar was cleaned up, along with some duplicate statements. The changes significant to the spec are:

- **Renumbering**
  - From Section 6.3.10 to 6.3.20 and 6.3.11 to 6.3.21 since 6.3.10 is used by UCC.
  - The DOCSIS editor may with to include section 9 in "9.4 Dynamic Operation" instead of "9.3 Standard Operation".
- **6.3.10 UCC-REQ**
  - Added a note indicating that the footnote needs updating.
- **6.3.20.1.3 UCD Technique**
  - Added this TLV
- **6.3.20.1.4 Ranging Technique TLV**
  - Removed the phase "*If this TLV is absent, the CM MUST perform ranging with initial maintenance. For backwards compatibility, the CMTS MUST accept a CM which ignores this tuple and performs initial maintenance*" since DCC is only a DOCSIS 1.1 command.
  - Added a statement regarding the delay before operation as a result of the different ranging choices.
- **6.3.20.1.5 Connection Technique TLV**
  - Changed "Configuration TLV" to "Connection TLV" throughout the document.
- **6.3.21 DCC-RSP**
  - Removed the DCC-Status TLV. DCC-RSP now has no parameters. I did this because the the criteria for declaring a change-over successful was not consistent under all test conditions, and it was difficult to arrive at a criteria that the CMTS and CM could use reliably. Also, the old QoS resources were kept around for 35 sec instead of only 2 sec as they are now. I think this also simplifies the overall proposal without sacrificing quality.
- **9.3.4 Changing Channels...**

- Re-organized into 4 sub-sections to improve readability. Updated CMTS and CM state machines. Added a example transaction diagram.

DCC General Operation

- Added a MUST for CM operation to the end of the first paragraph.
- Removed "*If the CM has previously established ranging on the new channel, and if that ranging on that channel is still current (T4 has not elapsed since the last successful ranging), then the CM MAY use cached ranging information and omit re-ranging.*" per Andrews suggestion. It was a lay-over from UCC. Plus, it was not being shown in the state machine
- Removed "*The CM SHOULD cache UCD information from multiple upstream channels to eliminate waiting for a UCD corresponding to the new upstream channel.*" Another lay-over from UCC. The DCC command explicitly states how to treat UCD messages.

DCC Exception Conditions

- Added a note that the retries of DCC-REQ must be done on the old and new downstream channel.
- Added a note that if the CM fails on the new channel, it will return to the old channel assignment and re-initialize.
- Added a note that stated clearly that the CM must not act on duplicate DCC-REQ commands and respond with a DCC-RSP.

Seamless Operation

- Added a note that in order to provide seamless operation, the CMTS will have to duplicate the downstream packet on both the old and new channels during change-over.
- Added an explicit list of MUST conditions.

Example Operation

- Describes interaction with other MAC messages.

- **Appendix B:**
  - Removed T11 and T12 (these were added in rev 0.6). T5 is now used exclusively.

Update on Rev 0.8, 2/27/00

This update is based upon review comments received from the DOCSIS 1.1 group on 2/22/00.

- Added a preface section which details required changes elsewhere in the I03 document
  - Noted updated needed to Figure 6-17
- **6.3.20 DCC-REQ**
  - Added Transaction ID.
  - Expanded Downstream parameters
  - Combined ranging TLV and configure TLV into one Initialization TLV
  - Removed SFID TLV.
- **6.3.21 DCC-RSP**
  - Added Transaction ID and Confirmation Code
  - DCC is now on old channel and new channel
- **6.3.22 DCC-ACK**
  - New message.

- **9.4.5.1 DCC General Operation**
  - Clarified that downstream ID and upstream ID must be unique.
  - Updated flow diagram and all state machines.
- **Appendix B**
  - Redid the timers. Now T11, T12, T13, T14
- **Appendix C.4**
  - Changed rejection code.
- **Appendix H**
  - Clarified that operation is single channel.

Update on Rev 0.90, 2/28/00

This update is based upon review comments received from the DOCSIS 1.1 group on 2/28/00.

- Renumbered section 9.3.4 to 9.4.5
- **6.3.20 DCC-REQ**
  - Added a SYNC Substitution TLV. This will potentially shave an additional 200 ms off of the change-over time.
- **9.5.4.1 DCC Operation**
  - Added a paragraph explaining that DCC-RSP does not gate QoS resources.
- **9.4.5.2 DCC Exceptions**
  - Added a paragraph explaining T14.
- **9.4.5.3 Seamless Channel Change**
  - Changed all MUSTs to SHOULDs
  - Added a CM SHOULD section
  - Added the concept of caching MAPs. This will shave an additional 5-20 ms off of the change-over time.
  - Updated flow diagram and state machines.

Update on Rev 0.91, 3/2/00

This update is prior to the review meeting of March 3, 2000

- **6.3.20 DCC-REQ**
  - Added SFID Substitution ID TLV back in.
  - Added Classifier ID Substitution TLV
  - Added PHSI Substitution TLV
- **Figures**
  - Figure 9-21, CM SM part 2 was down-rev. Update inserted.

Update on Rev 0.92, 3/3/00

These changes are a result of the DOCSIS 1.1 review meeting that took place on 3/3/00.

- **6.3.20 DCC-REQ**
  - Added HMAC digest
  - Added downstream channel ID to downstream parameters TLV
  - Combined SID, Classifier ID, and PHSI into sub-TLVs under Service Flow ID.
  - Added Grant-Sync TLV per ECN-RFI-00009.
  - Fixed type in Interleaver dept. J parameter was missing.
- **6.3.21 DCC-RSP**
  - Added HMAC digest
  - Changed figure to allow TLV field.
  - Added a reject-already-there(4) and reserved(5-255)
- **6.2.22 DCC-ACK**
  - Added HMAC digest
- **9.4.5.2 DCC Exception Conditions**
  - Added a sentence covering glare situation of CM had a DSx-ACK outstanding. This should also cover the case where a CM might do multiple independent and overlapping DSx commands.
- **9.4.5.3 Near-Seamless Channel Change**
  - Renamed from Seamless to Near-Seamless to be more accurate with the name and less binding.
  - Added notes to specify Grant Timing
  - Added a sentence alerting applications that packets may still get dropped in both directions.
- **Figures**
  - Renamed "leaving" to "depart" and "arrived" to "arrive"
  - If CM is already using the channels specified in DCC-REQ, the CM returns a reject message. The state diagrams make a distinction between different reject error codes

Update on Rev 0.93, 3/8/00

Mainly grammar updates and clarifications.

Got 2/3 of the way through Clive's comments.

This revision was released as an ECO update.

Update on Rev 0.94, 3/9/00

Finished Clive's comments. Added some from Mike St John and Lisa.

Mainly more grammar and clarifications.

One new item added regarding adding a CM Jump Time TLV to DCC-RSP

- **6.3.20.1.5 SYNC Substitution**
  - Added operational note about faster SYNCs.
- **6.3.21 DCC-RSP**
  - Moved error codes to Appendix C.4.2 to be consistent with RFI-o-00017.
  - Dropped reject-temporary and reject-permanent and pointed to C.4 codes instead
  - Allow any C.4 code to be used if it is appropriate.
- **9.4.5.3 Example Operation**
  - Clarified CMTS INIT bullet
  - Added CMTS SYNC bullet.
  - Add a operational note to the CMTS MAP bullet

Update on Rev 0.95, 3/10/00

The state transition diagrams were not working out for the CM due to the multiple conditional statements, so they have not been included.

- **6.3.20.1.7.5 Unsolicited Grant Synchronization Time**
  - Removed current sync time from the TLV.
- **9.4.5.3 Near-Seamless Channel Change**
  - Moved the "SHOULDs" which were not directly testable and not directly related to the CMTS to a separate bullet list and listed as "shoulds"
  - Added a comment regarding SCN usage to "shoulds" list.
- **Figures**
  - Changed "DCC-RSP (reject-temp/perm)" to "DCC-RSP (<reject-reason>)"
  - Updated Appendix H figures with SCTE standard symbols.

Outstanding Issues:

- none

Update on Rev 0.96, 3/14/00

From some e-mail review comments.

- **6.3.20.1 Encodings**
  - Added a comment indicating that not other parameters may change except the ones listed here.
- **6.3.20.1.2.5 Downstream Channel Identifier**
  - Added a comment indicating that the downstream channel identifier was unique.
- **6.3.20.1.3 Initialization Technique**
  - Added a comment indicating the ranging is done with the primary SID and that the primary SID may be substituted.
- **6.3.20.1.5 SYNC Substitution**
  - Added a comment clarify that synced timestamps are timestamps with the same clock and the same value.
- **9.4.5.2 DCC Exception Conditions**
  - Added a phase indicating that the DCC transaction must complete before the CM redoes the DSA.
- **9.5.4.3 Near Seamless Channel Change**
  - Changed wording to indicate the CMTS should use the same timestamp on both channels.
  - Moved wording regarding CM IP addresses.
- **9.4.5.4 Example Operation**
  - CM: SYNC and UCD where out of sequence
  - CM: Added a bullet for the MAP.

Update on Rev 0.97, 3/2200

- **6.3.6.3 Overriding Channels During Initial Ranging**
  - Added DCC-REQ reference to a paragraph that made reference to UCC.
- **6.3.20.1 DCC-REQ Encodings**
  - Added explicit MUST/SHOULD/MAY tags to each encoding. The format looks like: "The CMTS MUST/SHOULD/MAY include this TLV. The CM MUST/SHOULD/MAY observe this TLV".
  - I used MUST for TLVs that were needed to make the basics work; SHOULD for TLVs which enhanced performance; and MAYs for TLV which affected logical operation but where application dependent.
- **6.3.20.1.4 UCD Substitution**
  - Changed the grammar to singular from plural. Added "This TLV occurs once and contains one UCD" to introduction section.
- **6.3.21.1 DCC-RSP Encodings**
  - Added explicit MUST/SHOULD for CM.
- **9.4.5.1 DCC General Operation**
  - Clarified that T13 does not include any re-init time.
- **9.4.5.3 Near Seamless Channel Change**
  - Added bullet stating CM SHOULD include Jump Time.
- **H.2.2 Normal Operation**
  - Added RNG-RSP and DCC-REQ to Table H-1

Update on Rev 0.98, 3/28/00

DCC was changed from a MUST to MAY for both CMTS and CM.

- **6.3.20 DCC-REQ**
  - Add the adjective "DCC-capable" to CM
- **6.3.21 DCC-RSP**
  - Add to the first paragraph the phrase "A CM MAY support Dynamic Channel Change. If the CM supports Dynamic Channel Change, ... "
- **9.4.5.1 General Operation**
  - Add the adjective "DCC-capable" to CM
- **C.1.3.1.12 DCC Support**
  - Added a modem capability bit for DCC

Update on Rev 0.99, 5/30/00

- Incorporated RFI-N-00029 into Appendix H. For consistancy with the surrounding paragraphs,
  - "response" was changed to "Ranging Response"
  - "range response" was changed to "Ranging Response"
  - "range request" was changed to "Ranging Request"
  - "ranging-response" was changed to "Ranging Response"

~~5.2 Support for Multiple Channels~~

~~*Figure 6-28.*~~

~~*6.3.3 Upstream Channel Descriptor (UCD)*~~

~~6.3.19~~

Revisions Required to other Areas of DOCSIS 1.1 to support this proposal.

- **6.3.1 MAC Management Message Header**

  Table 6-17, page 91. Add the following message types 23 to 25 and modify comments for message types 26-255.

Type Value	Version	Message Name	Message Description
23	2	DCC-REQ	Dynamic Channel Change Request
24	2	DCC-RSP	Dynamic Channel Change Response
25	2	DCC-ACK	Dynamic Channel Change Acknowledge
26-255			Reserved for future use

- **6.3.6.3 Overriding Channels During Initial Ranging**

  Change the last sentence of the last paragraph from:

  "Once ranging is complete, only the C.1.1.2 and UCC-REQ mechanisms are available for moving the modem to a new upstream channel, and only the C.1.1.1 mechanism is available for moving the modem to a new downstream channel."

  to:

  "Once ranging is complete, only the C.1.1.2, UCC-REQ, and DCC-REQ mechanisms are available for moving the modem to a new upstream channel, and only the C.1.1.1 mechanism and DCC-REQ is available for moving the modem to a new downstream channel."

- **6.3.10 Upstream Channel Change Request (UCC-REQ)**

  Change the footnote on page 94 of 103 from:

  " This value authorizes a CM to use an initial maintenance or station maintenance region, which ever occurs first. This value might be used when there is uncertainty when the CM may execute the UCC and thus a chance that it might miss station maintenance slots."

  to:

  " This value authorizes a CM to use an initial maintenance or station maintenance region, which ever the CM selects. This value might be used when there is uncertainty when the CM may execute the UCC and thus a chance that it might miss station maintenance slots.

  The footnote as stated creates a hardware incompatibility. This was noticed during one of the DCC review cycles.

6.3.20 Dynamic Channel Change -- Request (DCC-REQ)

A Dynamic Channel Change Request MAY be transmitted by a CMTS to cause a DCC-capable CM to change the upstream channel on which it is transmitting, the downstream channel it is receiving, or both.

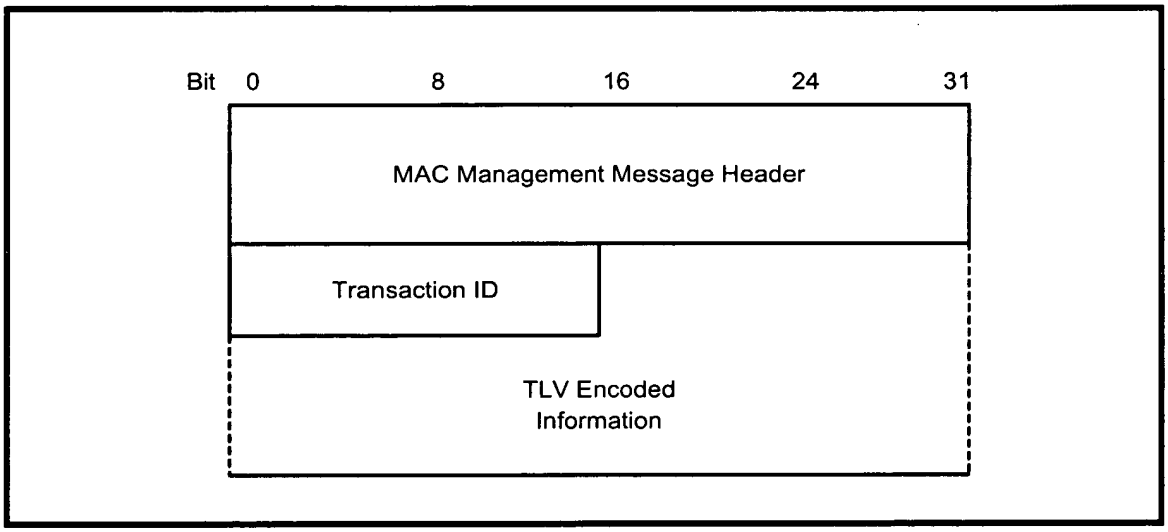

Figure 6-29. Dynamic Channel Change Request

A CMTS MUST generate DCC-REQ message in the form shown in Figure 6-29 including the following parameter:

Transaction ID A 16 bit unique identifier for this transaction assigned by the sender.;

The following parameters are optional and are coded as TLV tuples.

Upstream Channel ID The identifier of the upstream channel to which the CM is to switch for upstream transmissions.

Downstream Parameters The frequency of the downstream channel to which the CM is to switch for downstream reception.

Initialization Technique Directions for the type of initialization, if any, that the CM should perform once synchronized to the new channel(s).

UCD Substitution Provides a copy of the UCD for the new channel. This TLV occurs once and contains one UCD.

SAID Substitution A pair of Security Association Identifiers (SAID) which contain the current SAID and the new SAID for the new channel. This TLV occurs once if the SAID requires substitution.

Service Flow Substitution A group of sub-TLVs which allows substitution in a Service Flow of the Service Flow Identifier, Service Identifier, Classifier Identifier, and the Payload Header Suppression Index. This TLV is repeated for every Service Flow which has parameters requiring substitution.

If Privacy is enabled, a DCC-REQ MUST also contain:

HMAC-Digest The HMAC-Digest Attribute is a keyed message digest (to authenticate the sender). The HMAC-Digest Attribute MUST be the final Attribute in the Dynamic Channel Change message's Attribute list. (Refer to Appendix Appendix C.1.4.1)

6.3.20.1 Encodings

The type values used MUST be those shown below. These are unique within the Dynamic Channel Change Request message, but not across the entire MAC message set.

If a CM performs a channel change without performing a re-initialization (as defined in Section), then all the configuration variables of the CM MUST remain constant, with the exception of the configuration variables which are explicitly changed below. The CM will not be aware of any configuration changes other than the ones that have been supplied in the DCC command, so consistency in provisioning between the old and new channels is important.

6.3.20.1.1 Upstream Channel ID

When present, this TLV specifies the new upstream channel ID that the CM MUST use when performing a Dynamic Channel Change. It is an override for the current upstream channel ID. The CMTS MUST ensure that the Upstream Channel ID for the new channel is different than the Upstream Channel ID for the old channel. This TLV MUST be included if the upstream channel is changed, even if the UCD substitution TLV is included.

Type	Length	Value
1	1	0-255: Upstream Channel ID

If this TLV is missing, the CM MUST NOT change its upstream channel ID. The CMTS MAY include this TLV. The CM MUST observe this TLV.

6.3.20.1.2 Downstream Parameters

When present, this TLV specifies the operating parameters of the new downstream channel. The value field of this TLV contain a series of sub-types. The CMTS MUST include all sub-types.

Type	Length	Value
2	n	

If this TLV is missing, the CM MUST NOT change its downstream parameters.

6.3.20.1.2.1 Downstream Frequency

This TLV specifies the new receive frequency that the CM MUST use when performing a Dynamic Channel Change. It is an override for the current downstream channel frequency. This is the center frequency of the downstream channel in Hz and is stored as a 32-bit binary number. The downstream frequency MUST be a multiple of 62,500 Hz.

Subtype	Length	Value
2.1	4	Rx Frequency

The CMTS MUST include this sub-TLV. The CM MUST observe this sub-TLV.

6.3.20.1.2.2 Downstream Modulation Type

This TLV specifies the modulation type that is used on the new downstream channel.

Subtype	Length	Value
2.2	1	0 = 64 QAM 1 = 256 QAM 2 - 255: reserved

The CMTS SHOULD include this sub-TLV. The CM SHOULD observe this sub-TLV.

6.3.20.1.2.3 Downstream Symbol Rate

This TLV specifies the symbol rate that is used on the new downstream channel.

Subtype	Length	Value
2.3	1	0 = 5.056941 Msym/sec 1 = 5.360537 Msym/sec 2 = 6.952 Msym/sec 3 - 255: reserved

The CMTS SHOULD include this sub-TLV. The CM SHOULD observe this sub-TLV.

6.3.20.1.2.4 Downstream Interleaver Depth

This TLV specifies the parameters "I" and J of the downstream interleaver.

Subtype	Length	Value
2.4	2	I: 0-255 J: 0-255

The CMTS SHOULD include this sub-TLV. The CM SHOULD observe this sub-TLV.

6.3.20.1.2.5 Downstream Channel Identifier

This TLV specifies the 8 bit downstream channel identifier of the new downstream channel. The CMTS MUST ensure that the Downstream Channel ID for the new channel is different than the Downstream Channel ID for the old channel.

Subtype	Length	Value
2.5	1	0-255: Downstream Channel ID.

The CMTS SHOULD include this sub-TLV. The CM SHOULD observe this sub-TLV.

6.3.20.1.3 Initialization Technique

When present, this TLV allows the CMTS to direct the CM as to what level of re-initialization, if any, it MUST perform before it can commence communications on the new channel(s). The CMTS can make this decision based upon its knowledge of the differences between the old and new MAC domains and the PHY characteristics of their upstream and downstream channels.

Typically, if the move is between upstream and/or downstream channels within the same MAC domain, then the connection profile values may be left intact. If the move is between different MAC domains, then a complete initialization may be performed.

If a complete re-initialization is not required, some re-ranging may still be required. For example, areas of upstream spectrum are often configured in groups. A DCC-REQ to an adjacent upstream channel within a group may not warrant re-ranging. Alternatively, a DCC-REQ to a non-adjacent upstream channel might require station maintenance whereas a DCC-REQ from one upstream channel group to another might require initial maintenance. Re-ranging may also be required if there is any difference in the PHY parameters between the old and new channels.

Type	Length	Value
3	1	0 = Reinitialize the MAC 1 = Perform initial maintenance on new channel before normal operation. 2 = Perform station maintenance on new channel before normal operation. 3 = Perform either initial maintenance or station maintenance on new channel before normal operation. 4 = Use the new channel(s) directly without re-initializing or performing initial or station maintenance 5 - 255: reserved

The CM MUST first select the new upstream and downstream channels based upon the Upstream Channel ID TLV (refer to Section 6.3.20.1.1) and the Downstream Frequency TLV (refer to Section 6.3.20.1.2.1). Then the CM MUST follow the directives of this TLV. For option 0, the CM MUST begin with the Initialization SID. For options 1 to 4 the CM MUST continue to use the primary SID for ranging. A SID Substitution TLV (see Section 6.3.21.1.7.2) may specify a new primary SID for use on the new channel (refer to Section).

Option 0: This option directs the CM to perform all the operations associated with initializing the CM (refer to Section 9.2). This includes all the events after acquiring downstream QAM, FEC, and MPEG lock and before Standard Operation (refer to Section 9.3), including obtaining a UCD, ranging, establishing IP connectivity, establishing time of day, transfer of operational parameters, registration, and baseline privacy initialization. When this option is used, the only other TLVs in DCC-REQ that are relevant are the Upstream Channel ID TLV and the Downstream Parameters TLV. All other DCC-REQ TLVs are irrelevant.

Option 1: If initial maintenance is specified, operation on the new channel could be delayed by several Ranging Intervals (see Appendix B).

Option 2: If station maintenance is specified, operation on the new channel could be delayed by the value of T4 (see Appendix B).

Option 3: This value authorizes a CM to use an initial maintenance or station maintenance region, which ever the CM selects. This value might be used when there is uncertainty when the CM may execute the DCC command and thus a chance that it might miss station maintenance slots.

Option 4: This option provides for the least interruption of service, and the CM may continue its normal operation as soon as it has achieved synchronization on the new channel. This option is intended for use with a near-seamless channel change (refer to Section 9.4.5.3).

Note: This option should not be used in physical plants where upstream transmission characteristics are not consistent.

If this TLV is absent, the CM MUST re-initialize the MAC. The CMTS MAY include this TLV. The CM MUST observe this TLV.

6.3.20.1.4 UCD Substitution

When present, this TLV allows the CMTS to send an Upstream Channel Descriptor message to the CM. This UCD message is intended to be associated with the new upstream and/or downstream channel(s). The CM stores this UCD messages in its cache, and uses it after synchronizing to the new channel(s).

Type	Length	Value
4	n	UCD for the new upstream channel

This TLV includes all parameters for the UCD message as described in section Section 6.3.3 except for the MAC Management Message Header. The CMTS MUST ensure that the change count in the UCD matches the change count in the UCDs of the new channel(s). The CMTS MUST ensure that the Upstream Channel ID for the new channel is different than the Upstream Channel ID for the old channel.

If the CM has to wait for a new UCD message when changing channels, then operation may be suspended for a time up to the "UCD Interval" (see Appendix B) or longer, if the UCD message is lost.

The CMTS SHOULD include this TLV. The CM SHOULD observe this TLV.

6.3.20.1.5 SYNC Substitution

When present, this TLV allows the CMTS to inform the CM to wait or not wait for a SYNC message before proceeding. The CMTS MUST have synchronized timestamps between the old and new channel(s) if it instructs the CM to not wait for a SYNC message before transmitting on the new channel. Synchronized timestamps implies that the timestamps are derived from the same clock and contain the same value.

Type	Length	Value
5	1	0 = acquire SYNC message on the new downstream channel before proceeding 1 = proceed without first obtaining the SYNC message 2 - 255: reserved

If this TLV is absent, the CM MUST wait for a SYNC message on the new channel before proceeding. If the CM has to wait for a new SYNC message when changing channels, then operation may be suspended for a time up to the "SYNC Interval" (see Appendix B) or longer, if the SYNC message is lost or is not synchronized with the old channel(s).

An alternative approach is to send SYNC messages more frequently (every 10 ms for example), and continue to require the CM to wait for a SYNC message before proceeding. This approach has the slightly more latency, but provides an additional check to prevent the CM from transmitting at an incorrect time interval.

The CMTS SHOULD include this TLV. The CM SHOULD observe this TLV.

6.3.20.1.6 Security Association Identifier (SAID) Substitution

When present, this TLV allows the CMTS to replace the Security Association Identifier (SAID) in the current Service Flow with a new Security Association Identifier. The baseline privacy keys associated with the SAID MUST remain the same. The CM does not have to simultaneously respond to the old and new SAID.

Type	Length	Value
6	4	current SAID (lower order 14 bits of a 16 bits field), new SAID (lower order 14 bits of a 16 bit field)

If this TLV is absent, the current Security Association Identifier assignment is retained. The CMTS MAY include this TLV. The CM MUST observe this TLV.

6.3.20.1.7 Service Flow Substitutions

When present, this TLV allows the CMTS to replace specific parameters within the current Service Flows on the current channel assignment with new parameters for the new channel assignment. One TLV is used for each Service Flow that requires changes in parameters. The CMTS MAY choose to do this to help facilitate setting up new QoS reservations on the new channel before deleting QoS reservations on the old channel. The CM does not have to simultaneously respond to the old and new Service Flows.

This TLV allows resource assignments and services to be moved between two independent ID value spaces and scheduling entities by changing the associated IDs and indexes. ID value spaces that may differ between the two channels include the Service Flow Identifier, the Service ID, the Classifier Identifier, and the Payload Header Suppression Index. This TLV does not allow changes to Service Flow QoS parameters, classifier parameters, or PHS rule parameters.

The Service Class Names used within the Service Flow ID should remain identical between the old and new channels.

Type	Length	Value
7	n	list of subtypes

If this TLV is absent for a particular Service Flow, then current Service Flow and its attributes are retained. The CMTS MAY include this TLV. The CM MUST observe this TLV.

6.3.20.1.7.1 Service Flow Identifier Substitution

This TLV allows the CMTS to replace the current Service Flow Identifier (SFID) with a new Service Flow Identifier. Refer to Appendix C.2.2.3.2 for details on the usage of this parameter.

This TLV MUST be present if any other Service Flow subtype substitutions are made. If this TLV is included and the Service Flow ID is not changing, then the current and new Service Flow ID will be set to the same value.

Subtype	Length	Value
7.1	8	current Service Flow ID, new Service Flow ID

The CMTS MAY include this TLV. The CM MUST observe this TLV.

6.3.20.1.7.2 Service Identifier Substitution

When present, this TLV allows the CMTS to replace the Service Identifier (SID) in the current upstream Service Flow with a new Service Identifier. Refer to Appendix C.2.2.3.3 for details on the usage of this parameter.

Subtype	Length	Value
7.2	4	current SID (lower order 14 bits of a 16 bits field), new SID (lower order 14 bits of a 16 bits field)

If this TLV is absent, the current Service Identifier assignments are retained. The CMTS MAY include this TLV. The CM MUST observe this TLV.

6.3.20.1.7.3 Classifier ID Substitution

When present, this TLV allows the CMTS to replace the the current Classifier Identifier with a new Classifier Identifier. One TLV is used for each pair of old and new Classifier Identifier that are to be substituted within this Service Flow. Refer to Appendix C.2.1.3.2 for details on the usage of this parameter.

Subtype	Length	Value
7.3	4	current Classifier ID, new Classifier ID

If this TLV is absent, the current Classifier Identifier is retained. The CMTS MAY include this TLV. The CM MUST observe this TLV.

6.3.20.1.7.4 Payload Header Suppression Index Substitution

When present, this TLV allows the CMTS to replace the current Payload Header Suppression Index (PHSI) with a new Payload Header Suppression Index. Refer to Appendix C.2.2.10.2 for details on the usage of this parameter.

Subtype	Length	Value
7.4	2	current PHSI, new PHSI

If this TLV is absent, the current Payload Header Suppression Index is retained. The CMTS MAY include this TLV. The CM MUST observe this TLV.

6.3.20.1.7.5 Unsolicited Grant Time Reference Substitution

When present, this TLV allows the CMTS to replace the current Unsolicited Grant Time Reference with a new Unsolicited Grant Time Reference. Refer to Appendix C.2.2.6.11 for details on the usage of this parameter.

This TLV is useful if the old and new upstream use different time bases for their time stamps. This TLV is also useful if the Unsolicited Grant transmission window is moved to a different point in time. Changing this value may cause operation to temporarily exceed the jitter window specified by Appendix C.2.2.6.8.

Subtype	Length	Value
7.5	4	new reference

If this TLV is absent, the current Unsolicited Grant Time Reference is retained. The CMTS MAY include this TLV. The CM MUST observe this TLV.

6.3.21 Dynamic Channel Change -- Response (DCC-RSP)

A CM MAY support Dynamic Channel Change. If the CM supports Dynamic Channel Change, a Dynamic Channel Change Response MUST be transmitted by a CM in response to a received Dynamic Channel Change Request message to indicate that it has received and is complying with the DCC-REQ. The format of a DCC-RSP message MUST be as shown in Figure 6-30.

Before it begins to switch to a new upstream or downstream channel, a CM MUST transmit a DCC-RSP on its existing upstream channel. When a CM receives a DCC-REQ message requesting that it switch to an upstream and/or downstream channel that it is already using, the CM MUST respond with a DCC-RSP message on that channel indicating that it is already using the correct channel.

A CM MAY ignore a DCC-REQ message while it is in the process of performing a channel change.

After switching to a new channel, if the MAC was not re-initialized per DCC-REQ Initialization TLV, option 0, the CM MUST send a DCC-RSP message to the CMTS. A DCC-RSP MUST NOT be sent if the CM reinitializes its MAC.

The full procedure for changing channels is described in Section 9.4.5.

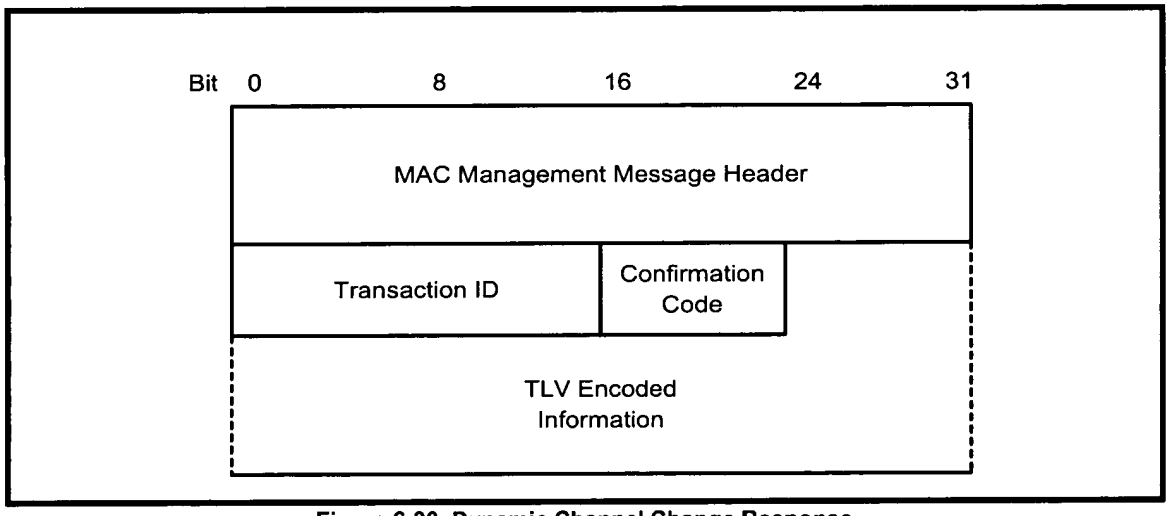

Figure 6-30. Dynamic Channel Change Response

Parameters MUST be as follows:

Transaction ID A 16 bit Transaction ID from corresponding DCC-REQ.

Confirmation Code An 8 bit Confirmation Code as described in Appendix C.4.1

The following parameters are optional and are coded as TLV tuples.

CM Jump Time Timing parameters describing when the CM will make the jump.

Regardless of success or failure, if Privacy is enabled for the CM the DCC-RSP MUST contain:

HMAC-Digest	The HMAC-Digest Attribute is a keyed message digest (to authenticate the sender). The HMAC-Digest Attribute MUST be the final Attribute in the Dynamic Channel Change message's Attribute list. (Refer to Appendix C.1.4.1)

6.3.21.1 Encodings

The type values used MUST be those shown below. These are unique within the Dynamic Channel Change Response message, but not across the entire MAC message set.

6.3.21.1.1 CM Jump Time

When present, this TLV allows the CM to indicate to the CMTS when the CM plans to perform its jump and be disconnected from the network. With this information, the CMTS MAY take preventative measures to minimize or to eliminate packet drops in the downstream due to the channel change.

Type	Length	Value
1	n	

The time reference and units of time for these sub-TLVs is based upon the same 32 bit time base used in the SYNC message on the current downstream channel. This timestamp is incremented by a 10.24 MHz clock

The CM SHOULD include this TLV. The CMTS SHOULD observe this TLV.

6.3.21.1.1.1 Length of Jump

This TLV indicates to the CMTS the length of the jump from the previous channel to the new channel. Specifically, it represents the length of time that the CM will not be able to receive data in the downstream.

Subtype	Length	Value
1	4	length (based upon timestamp)

The CM MUST include this sub-TLV.

6.3.21.1.1.2 Start Time of Jump

When present, this TLV indicates to the CMTS the time in the future that the CM is planning on making the jump.

Subtype	Length	Value
2	8	start time (based upon timestamp), accuracy of start time (based upon timestamp)

The 32 bit, 10.24 MHz time base rolls over approximately every 7 minutes. If the value of the start time is less than the the current timestamp, the CMTS will assume one roll-over of the timestamp counter has elapsed. The accuracy of the start time is an absolute amount of time before and after the start time.

The potential jump window is from (start time - accuracy) to (start time + accuracy + length).

The CM SHOULD include this TLV.

6.3.22 Dynamic Channel Change -- Acknowledge (DCC-ACK)

A Dynamic Channel Change Acknowledge MUST be transmitted by a CMTS in response to a received Dynamic Channel Change Response message on the new channel with its Confirmation Code set to arrive(1). The format of a DCC-ACK message MUST be as shown in Figure 6-31.

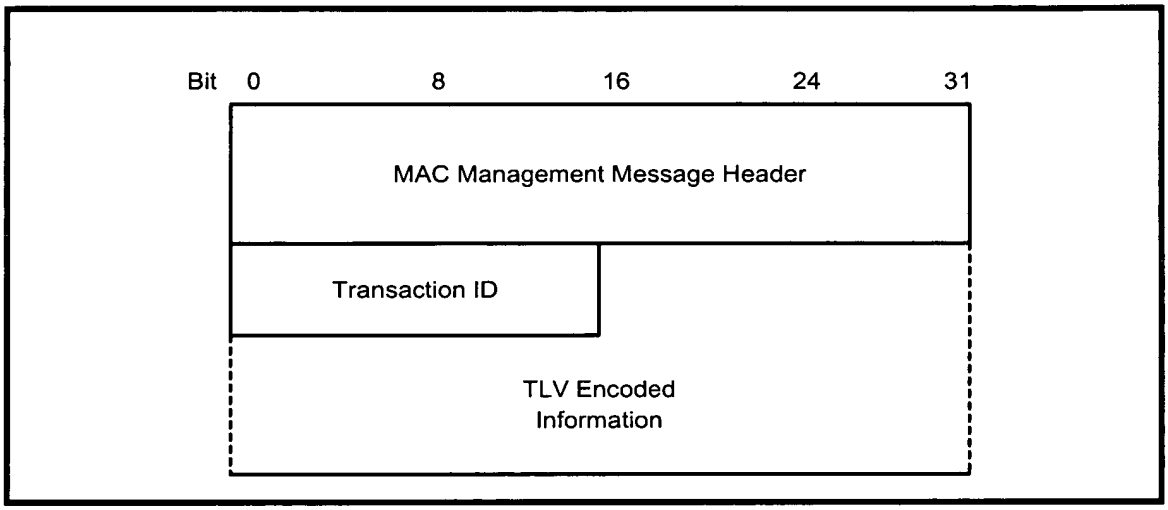

Figure 6-31. Dynamic Channel Change Acknowledge

Parameters MUST be as follows:

Transaction ID A 16 bit Transaction ID from corresponding DCC-RSP.

If Privacy is enabled, the DCC-ACK message MUST contain:

HMAC-Digest The HMAC-Digest Attribute is a keyed message digest (to authenticate the sender). The HMAC-Digest Attribute MUST be the final Attribute in the Dynamic Channel Change message's Attribute list. (Refer to Appendix Appendix C.1.4.1)

9 Cable Modem - CMTS Interaction

~~9.2 Cable Modem Initialization~~

~~9.3 Standard Operation~~

~~Figure 9-1.~~

~~9.4.4~~

~~Figure 9-16.~~

9.4.5 Dynamically Changing Downstream and/or Upstream Channels

9.4.5.1 DCC General Operation

At any time after registration, the CMTS MAY direct the CM to change its downstream and/or upstream channel. This may be done for traffic balancing, noise avoidance, or other reasons which are beyond the scope of this specification. Figure 9-18 shows the procedure that MUST be followed by the CMTS. Figure 9-20 shows the corresponding procedure that MUST be followed by a DCC-capable CM.

The DCC command can be used to change only the upstream frequency, only the downstream frequency, or both the upstream and downstream frequencies. When only the upstream or only the downstream frequency is changed, the change is typically within a MAC domain. When both the upstream and downstream frequencies are changed, the change may be within a MAC domain, or between MAC domains.

The Downstream Channel ID and the Upstream Channel ID MUST both be unique between the old and new channels. In this context, the old channel refers to the channel(s) that the CM was on before the jump, and the new channel refers to the channel(s) that the CM is on after the jump.

Upon synchronizing with the new upstream and/or downstream channel, the CM MUST use the technique specified in the DCC-REQ Initialization Technique TLV, if present, to determine if it should perform re-initialization, only ranging, or neither. If this TLV is not present in DCC-REQ, the CM MUST re-initialize its MAC on the new channel assignment. (Refer to Section). If the CM has been instructed to re-initialize, then the CMTS MUST NOT wait for a DCC-RSP to occur on the new channel.

If the CM is being moved within a MAC domain, then a re-initialization may not be required. If the CM is being moved between MAC domains, then a re-initialization may be required. Re-initializing, if requested, is done with the new upstream and channel assignments. It includes obtaining upstream parameters, establish IP connectivity, establish time of day, transfer operational parameters, register, and initialize baseline privacy. If re-initialization is performed, the CM MUST NOT send a DCC-RSP on the new channel.

The decision to re-range is based upon the CMTS's knowledge of any path diversity that may exist between the old and new channels, or if any of the fundamental parameters of the upstream or downstream channel such as symbol rate, modulation type, or minislot size have changed.

When DCC-REQ does not involve re-initialization or re-ranging, the design goal of the CM will typically be to minimize the disruption of traffic to the end user. To achieve this goal, a CM MAY choose to continue to use QoS resources (such as bandwidth grants) on its current channel after receiving a DCC-REQ and before actually executing the channel change. The CM might also need this time to flush internal queues or reset state machines prior to changing channels.

The CM MAY continue to use QoS resources on the old channel, including the transmission and reception of packets, after sending a DCC-RSP (depart) message and prior to the actual jump. The CM MAY use QoS resources on the new channel, including the transmission and reception of packets, after the jump and prior to sending a DCC-RSP (arrive) message. The CMTS MUST NOT use the DCC-RSP (depart) message to remove QoS resources on the old channel. The CMTS MUST NOT wait for a DCC-RSP (arrive) message on the new channel before allowing QoS resources to be used. This provision is to allow the Unsolicited Grant Service to be used on the old and new channel with a minimum amount of disruption when changing channels.

The CMTS MUST hold the QoS resources on the current channel until a time of T13 has passed after the last DCC-REQ that was sent, or until it can internally confirm the presence of the CM on the new channel assignment. The CM MUST execute the departure from the old channel and arriving at the new channel, less any commanded re-initialization, before the expiry of T13. The CM MAY continue to use QoS resources on the current channel after responding with DCC-RSP and before the expiry of T13.

Once the CM changes channels, all previous outstanding bandwidth requests made via the Request IE or Request/Data IE are invalidated, and the CM MUST re-request bandwidth on the new channel. In the case of Unsolicited Grant Service in the upstream, the grants are implicit with the QoS reservations, and do not need to be re-requested.

9.4.5.2 DCC Exception Conditions

If a CM issues a DSA-REQ or DSC-REQ for more resources, and the CMTS needs to do a DCC to obtain those resources, the CMTS will reject the DSA or DSC command without allocating any resources to the CM. The CMTS includes a confirmation code of "reject-temporary-DCC" (refer to Appendix C.1.3.1) in the DSC-RSP message to indicate that the new resources will not be available until a DCC is received. The CMTS will then follow the DSA or DSC transaction with a DCC transaction.

After the CM jumps to a new channel and completes the DCC transaction, the CM retries the DSA or DSC command. If the CM has not changed channels after the expiry of T14, as measured from the time that the CM received DSA-RSP or DSC-RSP from the CMTS, then the CM MAY retry the resource request.

If the CMTS needs to change channels in order to satisfy a resource request other than a CM initiated DSA or DSC command, then the CMTS should execute the DCC command first, and then issue a DSA or DSC command.

If a CMTS does a DCC with re-initialize, the config file could cause the CM to come back to the original channel. This would cause an infinite loop. To prevent this, if the provisioning system default is to specify the upstream channel ID and/or the downstream frequency, then the CMTS SHOULD NOT use DCC-REQ with the re-initialize option.

The CMTS MUST NOT issue a DCC command if the CMTS has previously issued a DSA, or DSC command, and that command is still outstanding. The CMTS MUST NOT issue a DCC command if the CMTS is still waiting for a DSA-ACK or DSC-ACK from a previous CM initiated DSA-REQ or DSC-REQ command.

The CMTS MUST NOT issue a DSA or DSC command if the CMTS has previously issued a DCC command, and that command is still outstanding.

If the CMTS issues a DCC-REQ command and the CM simultaneously issues a DSA-REQ or DSC-REQ then the CMTS command takes priority. The CMTS responds with a confirmation code of "reject-temporary" (refer to Appendix C.1.3.1). The CM proceeds with executing the DCC command.

If the CM is unable to achieve communications with a CMTS on the new channel(s), it MUST return to the previous channel(s) and re-initialize its MAC. The previous channel assignment represents a known good operating point which should speed up the re-initialization process. Also, returning to the previous channel provides a more robust operational environment for the CMTS to find a CM that fails to connect on the new channel(s).

If the CMTS sends a DCC-REQ and does not receive a DCC-RSP within time T11, it MUST retransmit the DCC-REQ up to a maximum of "DCC-REQ Retries" (Appendix B) before declaring the transaction a failure. Note that if the DCC-RSP was lost in transit and the CMTS retries the DCC-REQ, the CM may have already changed downstream channels.

If the CM sends a DCC-RSP on the new channel and does not receive a DCC-ACK from the CMTS within time T12, it MUST retry the DCC-RSP up to a maximum of "DCC-ACK Retries" (Appendix B).

If the CM receives a DCC-REQ with the Upstream Channel ID TLV, if present, equal to the current Upstream Channel ID, and the Downstream Frequency TLV, if present, is equal to the current downstream frequency, then the CM MUST consider the DCC-REQ as a redundant command. The remaining DCC-REQ TLV parameters MUST NOT be executed, and the CM MUST return a DCC-RSP, with a confirmation code of "reject-already-there", to the CMTS (refer to Appendix C.4.1).

9.4.5.3 Near-Seamless Channel Change

When the CMTS wishes to add new QoS reservations to a CM, it may be necessary to move that CM to a new upstream and/or downsteam to achieve that goal. During that changing of channels, it is desirable to provide the minimum of interruption to existing QoS services such as voice over IP or video streaming sessions. This near-seamless channel change is the primary design goal of the DCC command. The CMTS MAY support a near-seamless channel change. The CM MAY support a near-seamless channel change.

The actions below are recommended operating procedures to implement a near-seamless channel change. The list assumes both the upstream and downstream channels are changing. A subset of the list would apply if only the upstream or downstream channel changed.

To support a near-seamless channel change, the following conditions should apply in the network:

- The physical layer parameters for the new upstream and downstream channels should not change with the old upstream and downstream channels. Note that a change in downstream parameters could invalidate the ranging parameters.
- The ranging parameters should not change between the old and new channels. This may require symmetrical cabling and plant conditions which are external to the CMTS.
- The CMTS should use the same time stamp and SYNC mechanism for all downstream channels.
- IP routing should be configured so that the CM and its attached CPEs can continue to use their existing IP addresses. This will avoid disruption to RTP sessions or other in progress applications.

To achieve a near-seamless channel change, the CMTS:

- SHOULD duplicate all the relevant QoS reservations for the CM on the old and new channel assignments before initiating a DCC-REQ.
- SHOULD duplicate downstream packet flow for the CM on the old and new channel assignments before initiating a DCC-REQ (for downstream channel changes).
- SHOULD transmit MAP messages for the new upstream channel on the old downstream channel for at least the duration of T13, if the old and new downstream channels share the same timestamp. (Note that if the CM cannot cache MAPs for the new upstream while on the old downstream

channel, then the channel change delay will be increased by the amount of time into the future that MAPs are generated. Thus, the CMTS SHOULD refrain from scheduling MAPs farther into the future than it needs to.)

- SHOULD specify the downstream and upstream parameters of the new channels prior to the CM jumping.
- SHOULD specify to not wait for a SYNC message on the new channel.
- SHOULD specify to skip initialization (as defined in Section).
- SHOULD specify to skip initial maintenance and station maintenance.
- SHOULD manage service flow substitutions between old and new SIDs, SAID, Service Flow IDs, Classifier IDs, Payload Header Suppression Indexes, and Unsolicited Grant Time Reference as required. Service Class Names SHOULD remain the same between the old and new channel(s).

To achieve a near-seamless channel change, the CM:

- SHOULD reply with estimates for CM Jump Time in the DCC-RSP message.
- SHOULD listen for and cache MAP messages on the old downstream that apply to the new upstream. This SHOULD be done during time T13.
- SHOULD use the downstream parameters and the UCD in its cache from the DCC command to force a quicker PHY convergence when jumping.
- SHOULD NOT wait for a SYNC message after PHY convergence and before transmitting, if the CMTS permits the CM to do so.
- SHOULD use the cached MAPS, if available, to allow a quicker start-up time.
- SHOULD minimize the disruption of traffic in either direction by allowing traffic to continue to flow in both directions up to the moment prior to the jump and then immediately after resynchronization to the new channel(s) has happened.
- SHOULD queue incoming data packets that arrive during the jump, and transmit them after the jump
- SHOULD discard VoIP packets after the jump that have caused the upstream Unsolicited Grant Service queue to exceed its limit, but no more than necessary.

Applications that are running over the DOCSIS path should be able to cope with the loss of packets that may occur during the time that the CM changes channels.

9.4.5.4 Example Operation

Figure 9-17 shows an example of the use of DCC and its relation to the other DOCSIS MAC messages. In particular, this example describes a scenario where the CM attempts to allocated new resources with a DSA message. The CMTS temporarily rejects the request, tells the CM to change channels, and then the CM re-requests the resources. This example (not including all exception conditions) is described below. Refer to Section 9.2 for more detail.

a) An event occurs, such as the CM issuing a DSA-REQ message.

b) The CMTS decides that it needs to change channels in order to service this resource request. The CMTS responds with a DSA-RSP message which includes a confirmation code of "reject-temporary-DCC" (refer to Appendix C.1.3.1) in the DSC-RSP message to indicate that the new resources are not available until a DCC is received. The CMTS now rejects any further DSA or DSC messages until the DCC command is executed.

c) The CMTS initiates QoS reservations on the new upstream and/or downstream channels. The QoS reservations include the new resource assignment along with all the current resource assignments assigned to the CM. In this example, both the upstream and downstream channels are changed.

d) To facilitate a near-seamless channel change, since the CMTS is not sure exactly when the CM will switch channels, the CMTS duplicates the downstream packet flow on the old and new downstream channels.

e) The CMTS issues a DCC-REQ command to the CM.

f) The CM sends a DCC-RSP (depart). The CM then cleans up its queues and state machines as appropriate and changes channels.

g) If there was a downstream channel change, the CM synchronizes to the QAM symbol timing, synchronizes the FEC framing, and synchronizes with the MPEG framing.

h) If the CM has been instructed to re-initialization, it does so with the new upstream and/or downstream channel assignment. The CM exits from the flow of events described here, and enters the flow of events described in Section 9.2 starting with the recognition of a downstream SYNC message.

i) The CM searches for a UCD message unless it has been supplied with a copy.

j) The CM waits for a downstream SYNC message unless it has been instructed not to wait for one.

k) The CM collects MAP messages unless it already has them available in its cache.

l) The CM performs initial maintenance and station maintenance unless it has been instructed to skip them.

m) The CM resumes normal data transmission with its new resource assignment.

n) The CM sends a DCC-RSP (arrive) message to the CMTS.

o) The CMTS responds with a DCC-ACK.

p) The CMTS removes the QoS reservations from the old channels. If the downstream packet flow was duplicated, the packet duplication would also be removed on the old downstream channel.

q) The CM re-issues its DSA-REQ command.

r) The CMTS reserves the requested resources and responds with a DSA-RSP.

s) The CM finishes with a DSA-ACK.

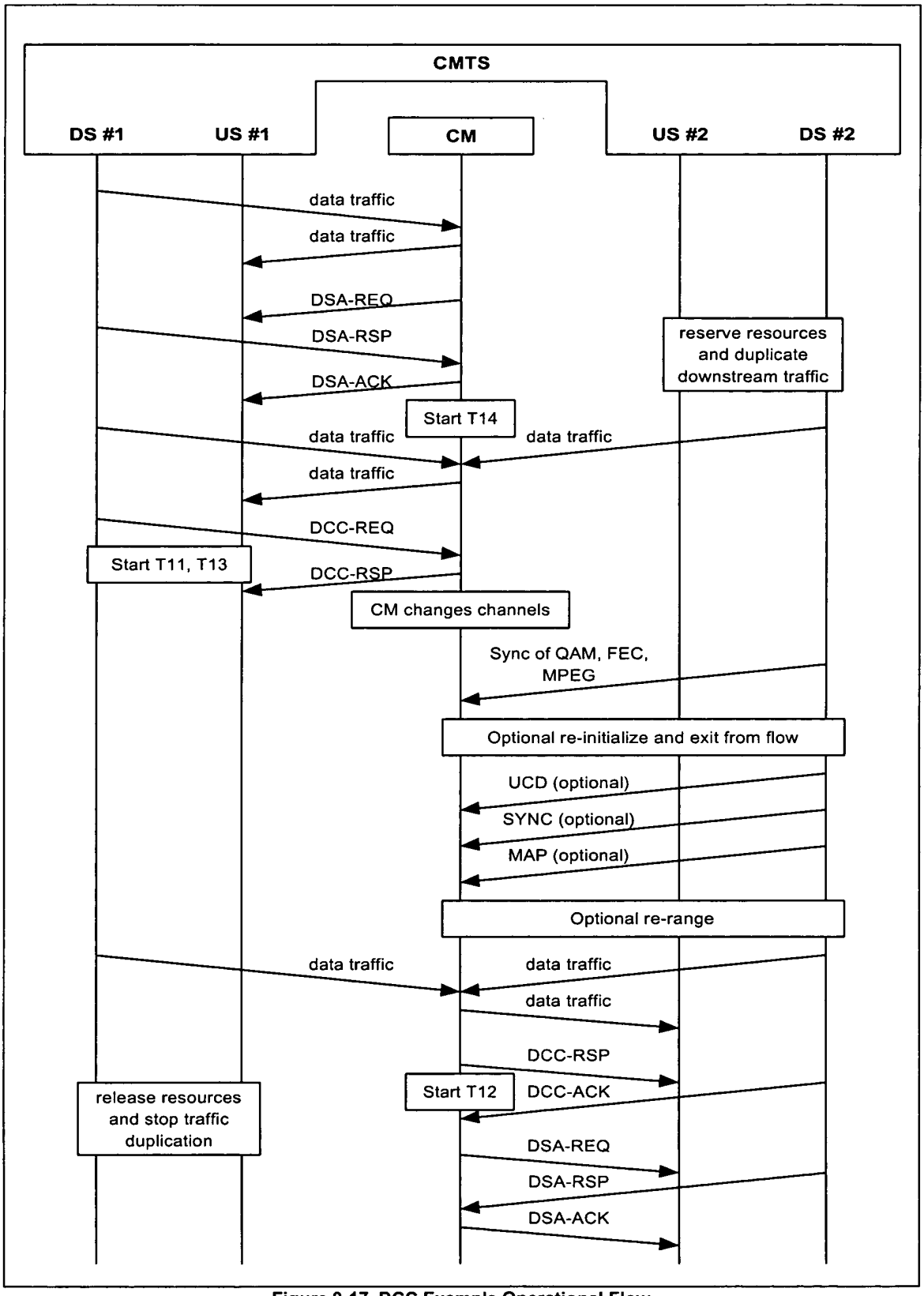

Figure 9-17. DCC Example Operational Flow

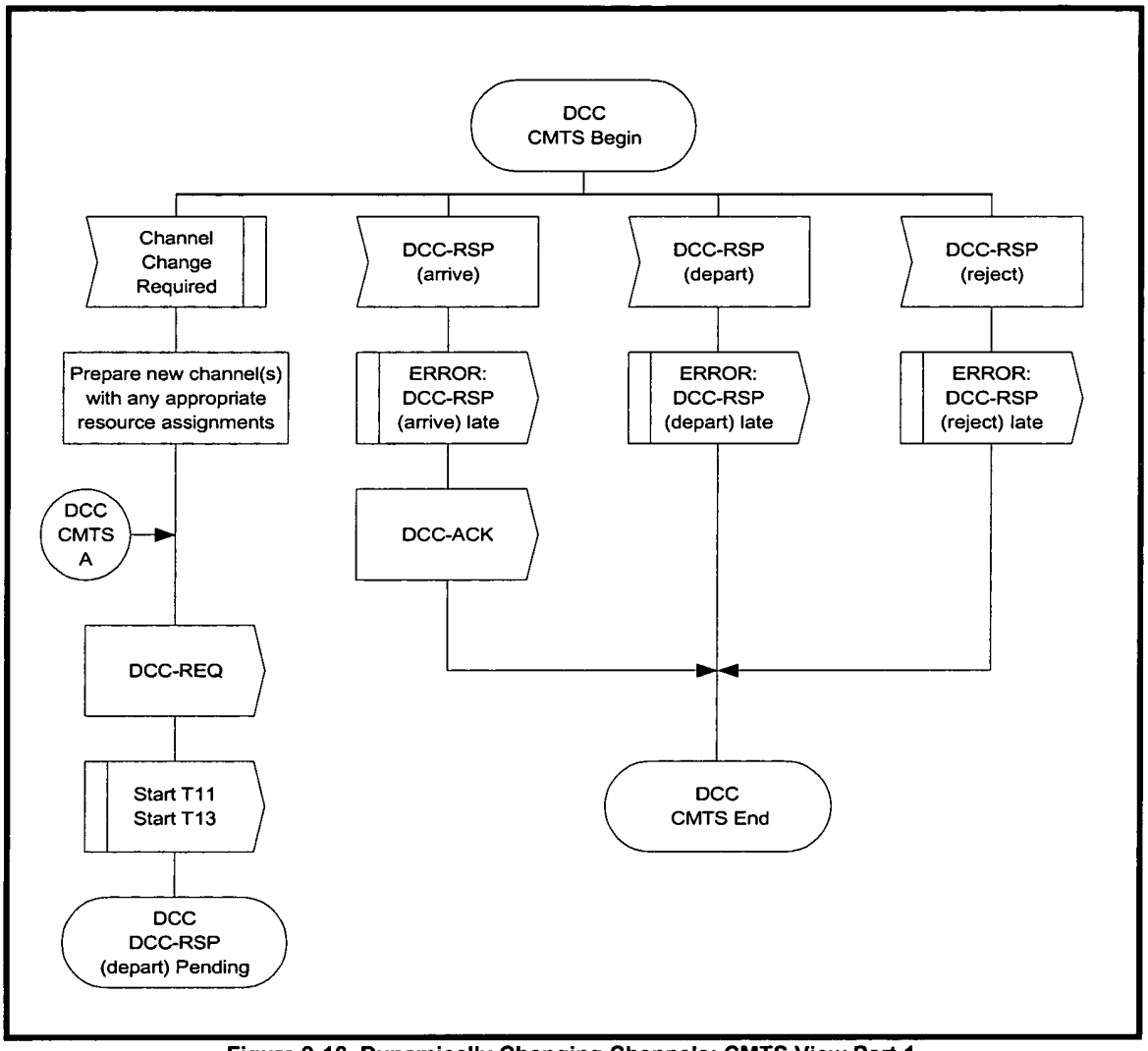

Figure 9-18. Dynamically Changing Channels: CMTS View Part 1

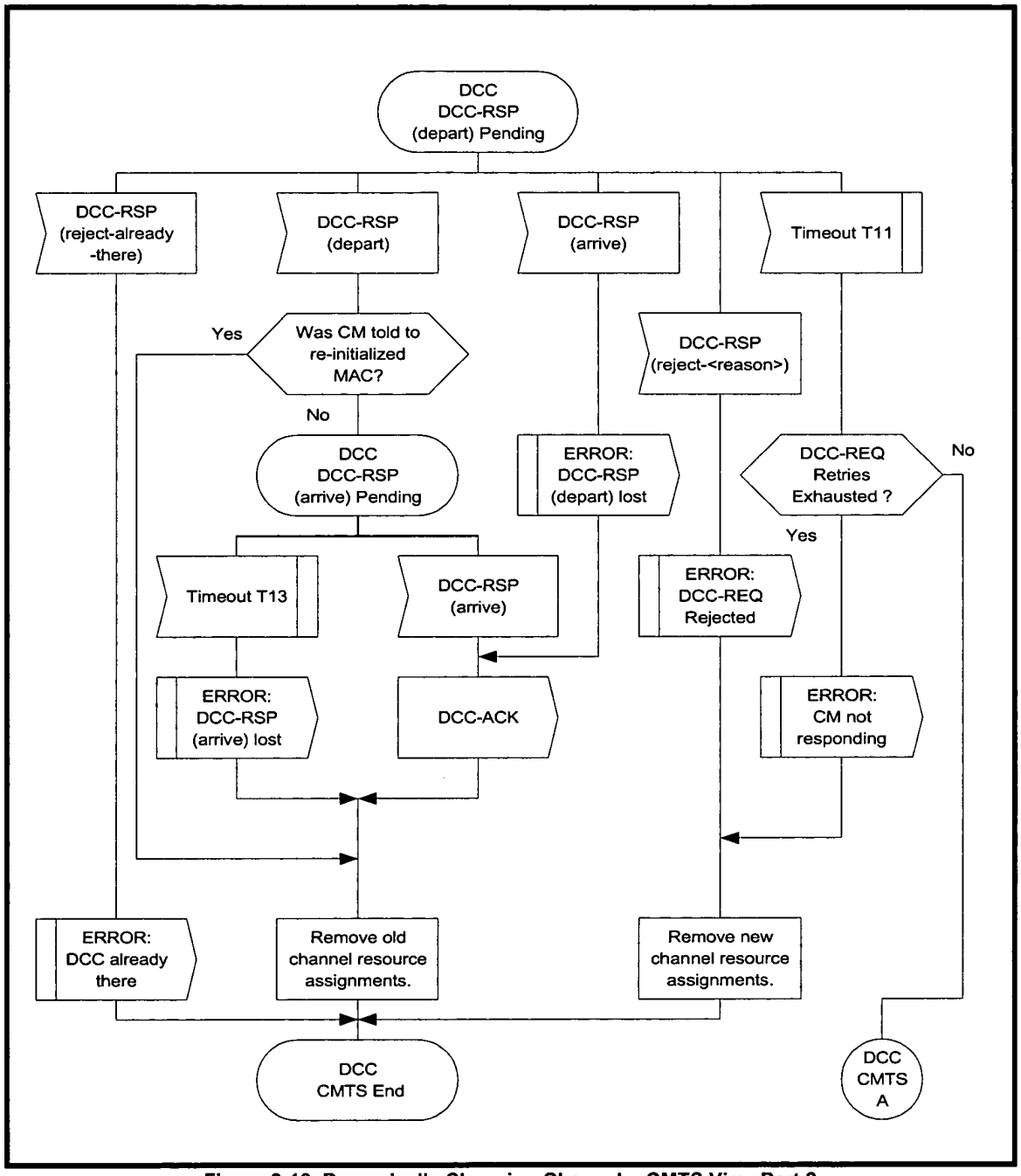

Figure 9-19. Dynamically Changing Channels: CMTS View Part 2

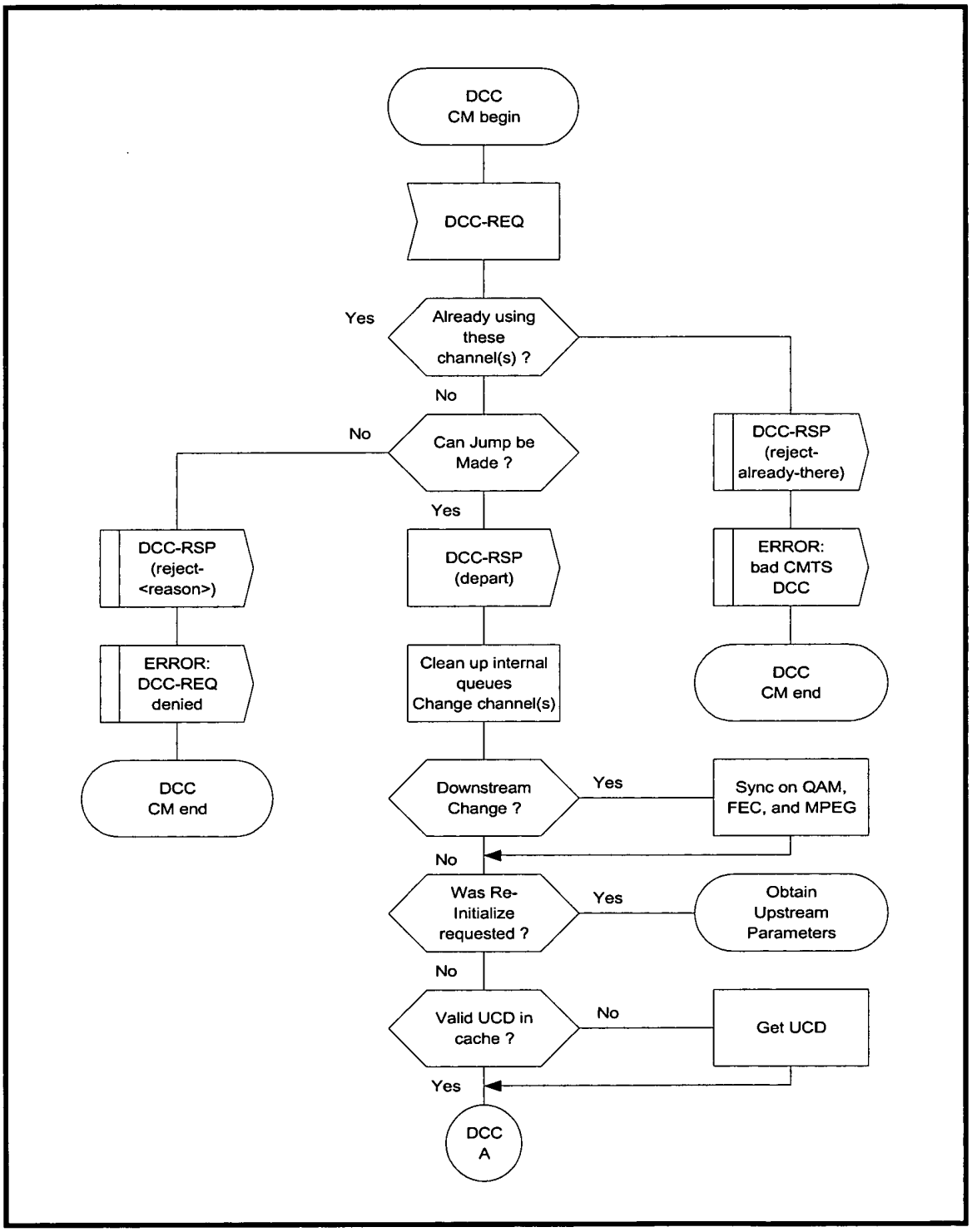

Figure 9-20. Dynamically Changing Channels: CM View Part 1[a]

a. The state "Obtain Upstream Parameters" links to the state machine in Figure 9-1.

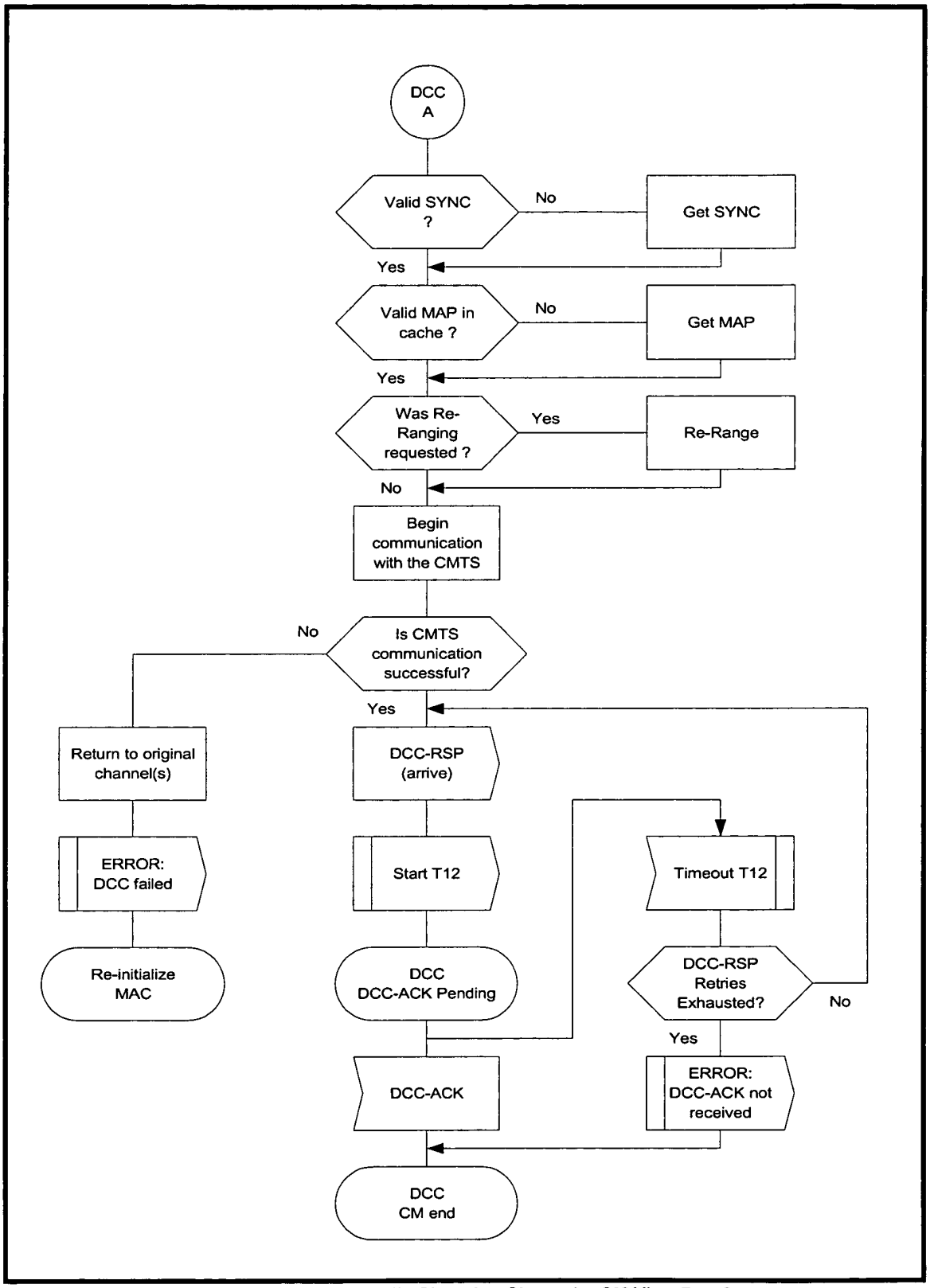

Figure 9-21. Dynamically Changing Channels: CM View Part 2

Appendix B. Parameters and Constants

System	Name	Time Reference	Minimum Value	Default Value	Maximum Value
CMTS	T11	Wait for a DCC Response on the old channel			300 ms
CM	T12	Wait for a DCC Acknowledge			300 ms
CMTS	T13	Maximum holding time for QOS resources for DCC			1 sec
CM	T14	Minimum time after a DSx reject-temp-DCC and the next retry of DSx command	2 sec		
CMTS	DCC-REQ Retries	Number of retries on Dynamic Channel Change Request	3		
CM	DCC-RSP Retries	Number of retries on Dynamic Channel Change Response	3		

C.1.3.1 Modem Capabilities Encoding

~~*C.1.3.1.11*~~

C.1.3.1.12 DCC Support

The value is the DCC support of the CM.

Type	Length	Value
5.12	1	0 = DCC is not supported 1 = DCC is supported

~~C.2 Quality of Service Related Encodings~~

~~*C.2.1.3.2 Classifier Identifier*~~

~~*C.2.2.3.2 Service Flow Identifier*~~

~~*C.2.2.3.3 Service Identifier*~~

~~*C.2.2.6.8 Tolerated Grant Jitter*~~

~~*C.2.2.6.11 Unsolicited Grant Time Reference*~~

~~*C.2.2.10.2 Payload Header Suppression Index (PHSI)*~~

C.4 Confirmation Code

Confirmation Code is one of the following ....

reject-temporary-DCC(25)

- reject-temporary-DCC(25) indicates that the requested resources are not available on the current channels at this time, and the CM should re-request them on new channels after completing a channel change in response to a DCC command which the CMTS will send. If no DCC is received, the CM must wait for a time of at least T14 before re-requesting the resources on the current channels.

C.4.1 Confirmation Codes for Dynamic Channel Change

The CM may return in the DCC-RSP message an appropriate rejection code from Appendix C.1.3.1. It may also return one of the following Confirmation Codes which are unique to DCC-RSP.

depart(180)
arrive(181)
reject-already-there(182)

The Confirmation Codes MUST be used in the following way:

- depart(180) indicates the CM is on the old channel and is about to perform the jump to the new channel.
- arrive(181) indicates the CM has performed the jump and has arrived at the new channel.
- reject-already-there(182) indicates that the CMTS has asked the CM to move to a channel that it is already occupying.

C.4.2 Confirmation Codes for Major Errors

Appendix H. Multiple Upstream Channels

This section is informational. In case of conflict between this section and any normative section of this specification, the normative section takes precedence.

Section 5.2 describes support for multiple upstream and multiple downstream channels within a DOCSIS domain. The permutations that a CM may see on the cable segment it is attached to include:

- single downstream and single upstream per cable segment
- single downstream and multiple upstreams per cable segment
- multiple downstreams and single upstream per cable segment
- multiple downstreams and multiple upstreams per cable segment

A typical application that will require one upstream and one downsteam per CM is web browsing. Web browsing tends to have asymmetrical bandwidth requirements that match closely to the asymmetrical bandwidth of DOCSIS.

A typical application that will require access to one of multiple upstreams per CM is IP Telephony. IP Telephony tends to have symmetrical bandwidth requirements. If there is a large concentration of CMs in a geographical area all served by the same fiber node, more than one upstream may be required in order to provide sufficient bandwidth and prevent call blocking.

A typical application that will require access to one of multiple downstreams per CM is IP streaming video. IP streaming video tends to have extremely large downstream bandwidth requirements. If there is a large concentration of CMs in a geographical area all served by the same fiber node, more than one downstream may be required in order to provide sufficient bandwidth and to deliver multiple IP Video Streams to multiple CMs.

A typical application that will require multiple downstreams and multiple upstreams is when the above applications are combined, and it is more economical to have multiple channels than it is to physically subdivide the HFC network.

The role of the CM in these scenarios would be to be able to move between multiple upstreams and between multiple downstreams. The role of the CMTS would be to manage the traffic load to all attached CMs, and balance the traffic between the multiple upstreams and downstreams by dynamically moving the CMs based upon their resource needs and the resources available.

This appendix looks at the implementation considerations for these cases. Specifically, the first and last application are profiled. These examples are meant to illustrate one topology and one implementation of that topology.

H.1 Single Downstream and Single Upstream per Cable Segment

This section presents an example of a single downstream channel and four upstream channels. In Figure H-1, the four upstream channels are on separate fibers serving four geographical communities of modems. The CMTS has access to the one downstream and all four upstreams, while each CM has access to the one downstream and only one upstream.

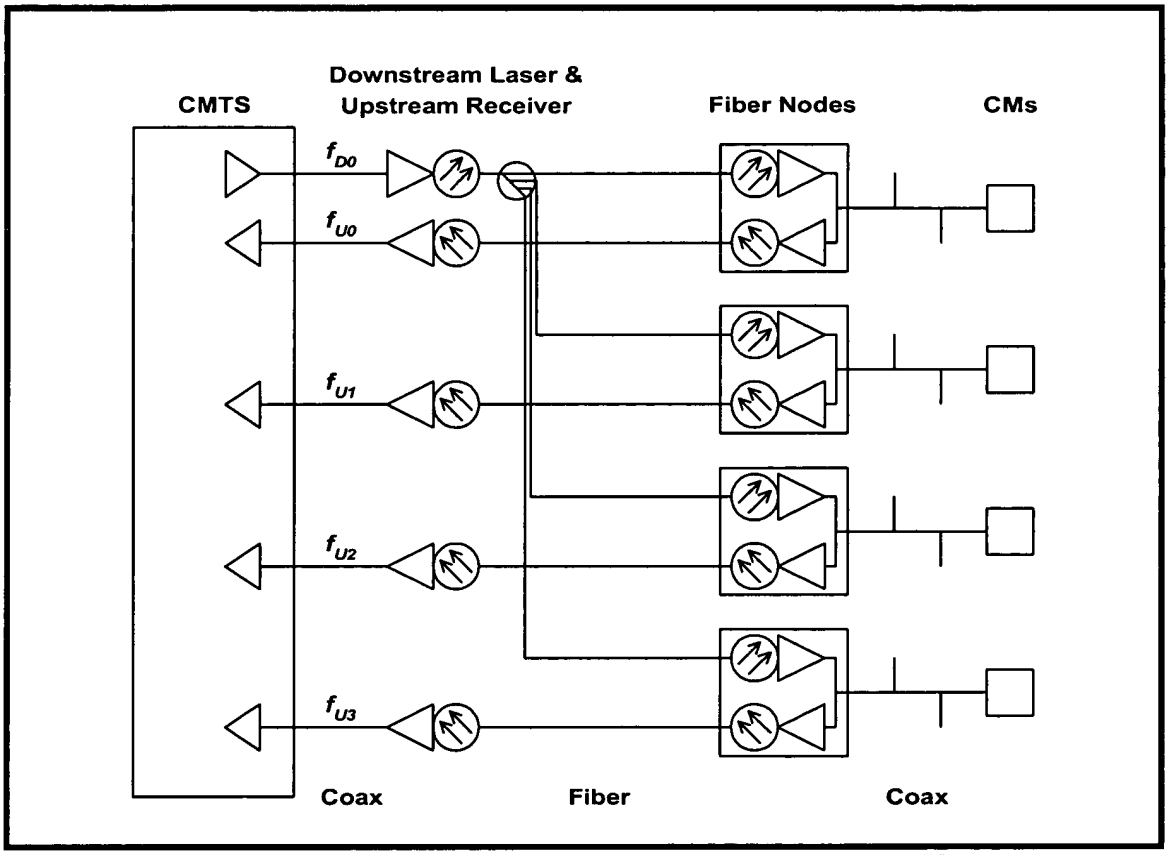

Figure H-1. Single Downstream and Single Upstream Channels per CM

In this topology, the CMTS transmits Upstream Channel Descriptors (UCDs) and MAPs for each of the four upstream channels related to the shared downstream channel.

Unfortunately, each CM cannot determine which fiber branch it is attached to because there is no way to convey the geographical information on the shared downstream channel. At initialization, the CM randomly picks a UCD and its corresponding MAP. The CM then chooses an Initial Maintenance opportunity on that channel and transmits a Ranging Request.

The CMTS will receive the Ranging Request and will redirect the CM to the appropriate upstream channel identifier by specifying the upstream channel ID in the Ranging Response. The CM MUST then use the channel ID of the Ranging Response, not the channel ID on which the Ranging Request was initiated. This is necessary only on the first Ranging Response received by the CM. The CM SHOULD continue the ranging process normally and proceed to wait for station maintenance IEs.

From then on, the CM will be using the MAP that is appropriate to the fiber branch to which it is connected. If the CM ever has to redo initial maintenance, it may start with its previous known UCD instead of choosing one at random.

A number of constraints are imposed by this topology:

- All Initial Maintenance opportunities across all fiber nodes must be aligned. When the CM chooses a UCD to use and then subsequently uses the MAP for that channel, the CMTS must be prepared to receive a Ranging Request at that Initial Maintenance opportunity. Note that only the initialization intervals must be aligned. Once the CM is successfully ranged on an upstream channel, its activities need only be aligned with other users on the same upstream channel. In Figure H-1, ordinary data transmission and requests for bandwidth may occur independently across the four upstream channels.
- All of the upstream channels on different nodes should operate at the same frequency or frequencies unless it is known that no other upstream service will be impacted due to a CM transmission of a Ranging Request on a "wrong" frequency during an Initial Maintenance opportunity. If the CM chooses an upstream channel descriptor arbitrarily, it could transmit on the wrong frequency if the selected UCD applied to an upstream channel on a different fiber node. This could cause initial maintenance to take longer. However, this might be an acceptable system trade-off in order to keep spectrum management independent between cable segments.
- All of the upstream channels may operate at different symbol rates. However, there is a trade-off involved between the time it takes to acquire ranging parameters and flexibility of upstream channel symbol rate. If upstream symbol rates are not the same, the CMTS would be unable to demodulate the Ranging Request if it was transmitted at the wrong symbol rate for the particular upstream receiver of the channel. The result would be that the CM would retry as specified in the RFI specification and then would eventually try other upstream channels associated with the currently used downstream. Increasing the probability of attempting ranging on multiple channels increases CM initialization time but using different symbol rates on different fiber nodes allows flexibility in setting the degree of burst noise mitigation.
- All Initial Maintenance opportunities on different channels may use different burst characteristics so that the CMTS can demodulate the Ranging Request. Again, this is a trade-off between time to acquire ranging and exercising flexibility in setting physical layer parameters among different upstream channels. If upstream burst parameters for Initial Maintenance are not the same, the CMTS would be unable to demodulate the Ranging Request if it was transmitted with the wrong burst parameters for the particular channel. The result would be that the CM would retry the Ranging Request as specified in the RFI specification and then would eventually try other upstream channels associated with the currently used downstream. Increasing the probability of attempting ranging on multiple channels increases CM initialization time but using different burst parameters for Initial Maintenance on different fiber nodes allows the ability to set parameters appropriate for plant conditions on a specific node.

H.2 Multiple Downstreams and Multiple Upstreams per Cable Segment

This section presents a more complex set of examples of CMs which are served by several downstream channels and several upstream channels and where those upstream and downstream channels are part of one MAC domain. The interaction of Initial Maintenance, normal operation, and Dynamic Channel Change are profiled, as well as the impact of the multiple downstreams using synchronized or unsynchronized timestamps.

Synchronized timestamps refer to both downstream paths transmitting a time stamp that is derived from a common clock frequency and have common time bases. The timestamps on each downstream do not have to be transmitted at the same time in order to be considered synchronized.

H.2.1 Topologies

Suppose two downstream channels are used in conjunction with four upstream channels as shown in Figure H-2. In all three topologies, there are two geographical communities of modems, both served by the same two downstream channels. The difference in the topologies is found in their upstream connectivity.

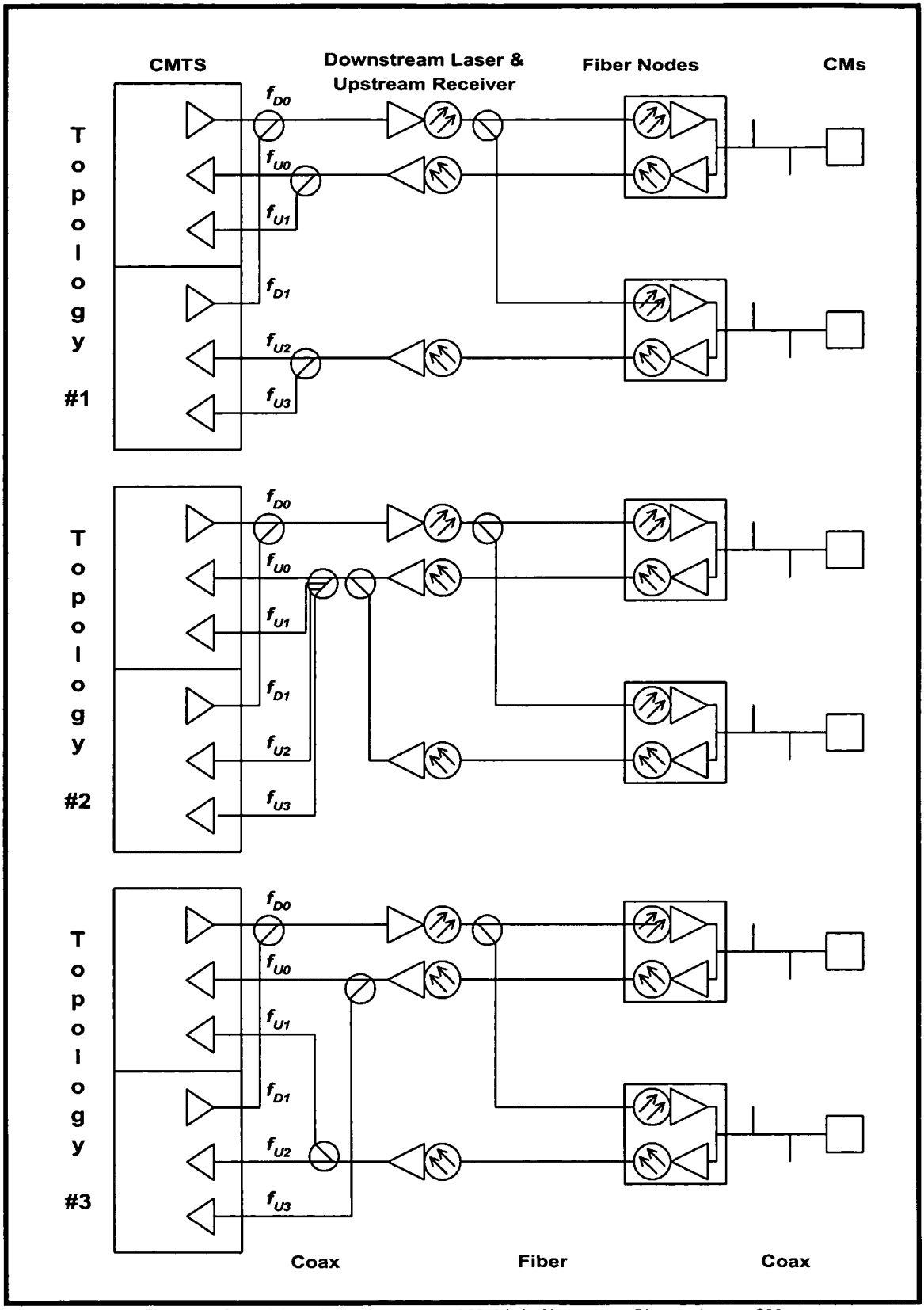

Figure H-2. Multiple Downstream and Multiple Upstream Channels per CM

Topology #1 has the return path from each fiber node connected to a dedicated set of upstream receivers. A CM will see both downstream channels, but only one upstream channel which is associated with one of the two downstream channels.

Topology #2 has the return path from each fiber node combined and then split across all upstream receivers. A CM will see both downstream channels and all four upstream channels in use with both downstream channels.

Topology #3 has the return path from each fiber node split and then sent to multiple upstream receivers, each associated with a different downstream channel. A CM will see both downstream channels, and one upstream channel associated with each of the two downstream channels.

Topology #1 is the typical topology in use. Movement between downstreams can only occur if the timestamps on both downstreams are synchronized. Topology #2 and Topology #3 are to compensate for downstreams which have unsynchronized timestamps, and allow movement between downstream channels as long as the upstream channels are changed at the same time.

The CMs are capable of single frequency receive and single frequency transmit.

H.2.2 Normal Operation

Table H-1 lists MAC messages that contain Channel IDs.

Table H-1. MAC Messages with Channel IDs

MAC Message	Downsteam Channel ID	Upstream Channel ID
UCD	Yes	Yes
MAP	No	Yes
RNG-REQ	Yes	No
RNG-RSP	No	Yes
DCC-REQ	Yes	Yes

With unsynchronized timestamps:

- Since upstream synchronization relies on downstream timestamps, each upstream channel must be associated with the time stamp of one of the downstream channels.
- The downstream channels should only transmit MAP messages and UCD messages that pertain to their associated upstream channels.

With synchronized timestamps:

- Since upstream synchronization can be obtained from either downstream channel, all upstreams can be associated with any downstream channel.
- All MAPs and UCDs for all upstream channels should be sent on all downstream channels. The UCD messages contains a Downstream Channel ID so that the CMTS can determine with the RNG-REQ message which downstream channel the CM is on. Thus the UCD messages on each downstream will contain different Downstream Channel IDs even though they might contain the same Upstream Channel ID.

H.2.3 Initial maintenance

When a CM performs initial maintenance, the topology is unknown and the timestamp consistency between downstreams is unknown. Therefore, the CM chooses either downstream channel and any one of the UCDs sent on that downstream channel.

In both cases:

- The upstream channel frequencies within a physical upstream or combined physical upstreams must be different.
- The constraints specified in Section H.1apply.

H.2.4 Dynamic Channel Change

With unsynchronized timestamps:

- When a DCC-REQ is given, it must contain new upstream and new downstream frequency pairs that are both associated with the same timestamp.
- When the CM resynchronizes to the new downstream, it must allow for timestamp resynchronization without re-ranging unless instructed to do so with the DCC-REQ command.
- Topology #1 will support channel changes between local upstream channels present within a cable segment, but will not support changes between downstream channels. Topology #2 and #3 will support upstream and downstream channel changes on all channels within the fiber node as long as the new upstream and downstream channel pair are associated with the same timestamp.

With synchronized timestamps:

- Downstream channel changes and upstream channel changes are independent of each other.
- Topology #1, #2, and #3 will support changes between all upstream and all downstream channels present within the cable segment.